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Eizenhoefer

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[54] **PROCESS FOR LOCATING MOBILE STATIONS IN A CELLULAR MOBILE RADIO NETWORK AND MOBILE RADIO NETWORK FOR CARRYING OUT THE PROCESS**

[75] Inventor: **Alfons Eizenhoefer**, Altdorf, Germany

[73] Assignee: **Daimler-Benz Aerospace AG**, Munich, Germany

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[52] **U.S. Cl.** **455/456**; 342/450

[58] **Field of Search** 379/59, 58; 455/33.1, 455/433, 456, 457; 342/450, 457

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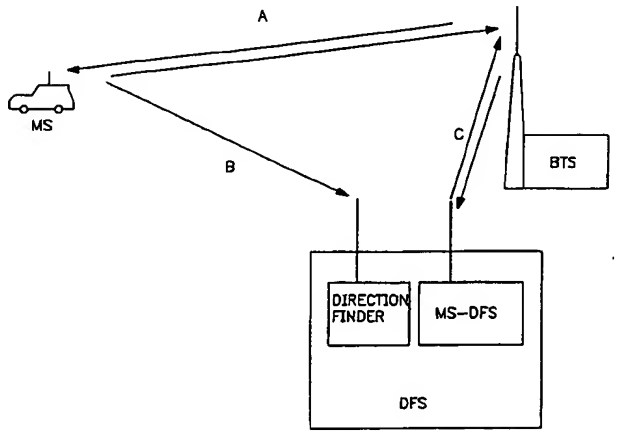
Primary Examiner—Dwayne D. Bost
Assistant Examiner—Myron K. Wyche
Attorney, Agent, or Firm—Spencer & Frank

[57] **ABSTRACT**

A process for locating mobile stations in a cellular mobile radio network with several spatially distributed fixed base stations associated each to several cells and several mobile stations. The network has storage devices which contain information about the identify of the mobile stations and about the cells in which the individual mobile stations were last signaled. In order to locate a mobile station in as flexible as possible a manner, but also if required as precisely as possible, the information in the storage devices is used for approximately locating the searched-for mobile station and at least one direction finding is carried out in order to more precisely locate the mobile station. A cellular mobile radio network for carrying out this process is characterized in that the individual stations are each in communication with a direction finder and that the mobile radio network has a locating central office in communication with all direction finders.

18 Claims, 8 Drawing Sheets



calls to the mobile stations MS, and via the jointly used control channel AGCH the base station BTS assigns dedicated channels to the mobile stations MS. Via the jointly used control channel RACH, the mobile stations MS access the network when they wish to make a connection.

The (calling or called) mobile station MS, during the buildup of the conversation, occupies a channel DCCH, assigned individually to it, with a low data rate. This is sufficient for signaling functions. Not until a traffic channel is needed for speech or data does the mobile station MS occupy a traffic channel TCH. One additional signaling channel SACCH with a low bit rate is also assigned to both channels.

All of these component groups and channels described in detail here are elements known per se in a mobile radio network according to the ETSI-GSM standard (see the aforementioned series of articles by H. Ochsner on the GSM network), which are also used in the mobile radio networks of FIGS. **1–3**.

Newly added in the mobile radio networks of FIGS. **1–3** are only the additional component groups DFS and LPC; DFS ("Direction Finding System") stands for the position or direction finders (one of which is shown in each of the drawings, by way of example), and LPC ("Location Processing Centre") stands for the central location processing office in which the location of the mobile station MS to be located is ascertained from the information provided from the home or visitor location registers HLR, VLR or from the analyzed results of the direction finding or transit time measurement.

The location finding in the GSM mobile radio networks of FIGS. **1–3** can be called a passive-subscriber process without mobile station support. The location finding is a one-time operation, which among other measurements comprises a plurality of individual measurements that succeed one another chronologically, from which the location of the mobile station MS sought is calculated.

Location tracking, conversely, makes it possible to plot the movement of a mobile station MS with different levels of accuracy. This is done by repeated application of the processes of location finding and evaluation of the results. The accuracy of the location tracking is largely determined by the accuracy of location finding. However, it is also conceivable for the accuracy to be improved by reprocessing with additional information (for example about the course of streets and roads).

The instantaneous location of a mobile station MS can be determined with different levels of accuracy. For instance, six service classes for location finding are conceivable, differing from one another in the degree of their accuracy:

PLMN Area Finding

VLR Area Finding

LA Finding

Cell Area Finding

Single Direction Finding

Multiple Direction Finding

The terms PLMN ("Public Land Mobile Network"), VLR "Visitor Location Area") and LA ("Location Area) are taken from the ETSI-GSM recommendations.

1. PLMN Area Finding:

Monitoring is done to find which mobile radio network the subscriber or mobile station MS is located in. Such a network is usually the size of a state. Monitoring is done by polling of data stored in the home location register HLR.

2. VLR Area Finding:

Monitoring is done to find which visitor location register VLR the subscriber or mobile station MS is registered in. A "VLR Area" is the region controlled by such a visitor location register VLR. It is usually several thousand square kilometers in size. The monitoring is done by polling of data stored in the home location register HLR.

3. Location Area Finding:

Monitoring is done as to which location area of a VLR area the subscriber or mobile station MS is located in. A "Location Area" LA contains a plurality of cells (typically from 3 to 20 of them) and has an area of typically from 100 km^2 to 10,000 km^2. Monitoring is done by polling of data stored in the visitor location register VLR.

4. Cell Area Finding:

At this level of accuracy, the location of a mobile station MS is determined with the accuracy of a "Cell Area" CA, which refers to a radio cell. The cell area is typically 2.5 km^2 in size in the inner city and up to 1000 km^2 in size in the country. In extreme cases, the cell area can cover up to 3000 km^2. The monitoring is done by calling the mobile station MS ("paging"). The mobile station MS then reports in the cell sought.

5. Single Direction Finding:

At this level of accuracy, the location of a mobile station MS is determined with high accuracy. The location determination is done from a base station BTS by means of at least one transit time measurement (distance) and by single or multiple position (direction) finding from a position finding station DFS (bearing angle; it suffices to determine the azimuth, among others). From these two indications, the location can then be determined. The prerequisite for single direction finding is cell area finding, because the cell in which the mobile station MS sought is currently located must be known so that it is possible to do the location finding.

6. Multiple Direction Finding:

At this level of accuracy, the location of a mobile station MS is determined with even higher accuracy. The location determination is done by single or multiple position (direction) finding from at least two direction finding stations DFS (bearing angle and azimuth angle, respectively). The transit time measurement (distance) from a base station BTS can be added in order to increase the accuracy, for instance if the two position (direction) finding directions intersect at an acute or flat angle. For multiple direction finding, the cell in which the subscriber is currently located must be known. Moreover, it must be possible to estimate which of the adjacent position finders DFS is suitable for position finding. To that end, the direction finders DFS that are assigned to both cells that are reported by the mobile station MS to the network as the most suitable neighboring cells for the direction finding are chosen.

During the location process, the mobile station MS is in radio contact (radio connection **1**) with the GSM network (BSS and SSS). This radio contact is as a rule taken up for the sake of the location finding unless it already exists. The direction finder DFS receives the radio signal from the mobile station MS (radio connection **2**) and takes a bearing on the direction from which this signal comes.

In a first version (FIG. **2** or FIG. **3**), the connection of the direction finder DFS to the GSM network (BSS, SSS) is also done by radio (radio connection **3**). The reports are transmitted to the visitor location register VLR, for instance via the "short message service" of the GSM. Making the connection by radio has the advantage of not needing any lines to the direction finder DFS, and of not requiring any